Asset Management of Cable Fleet

Dr. Aradhana Ray

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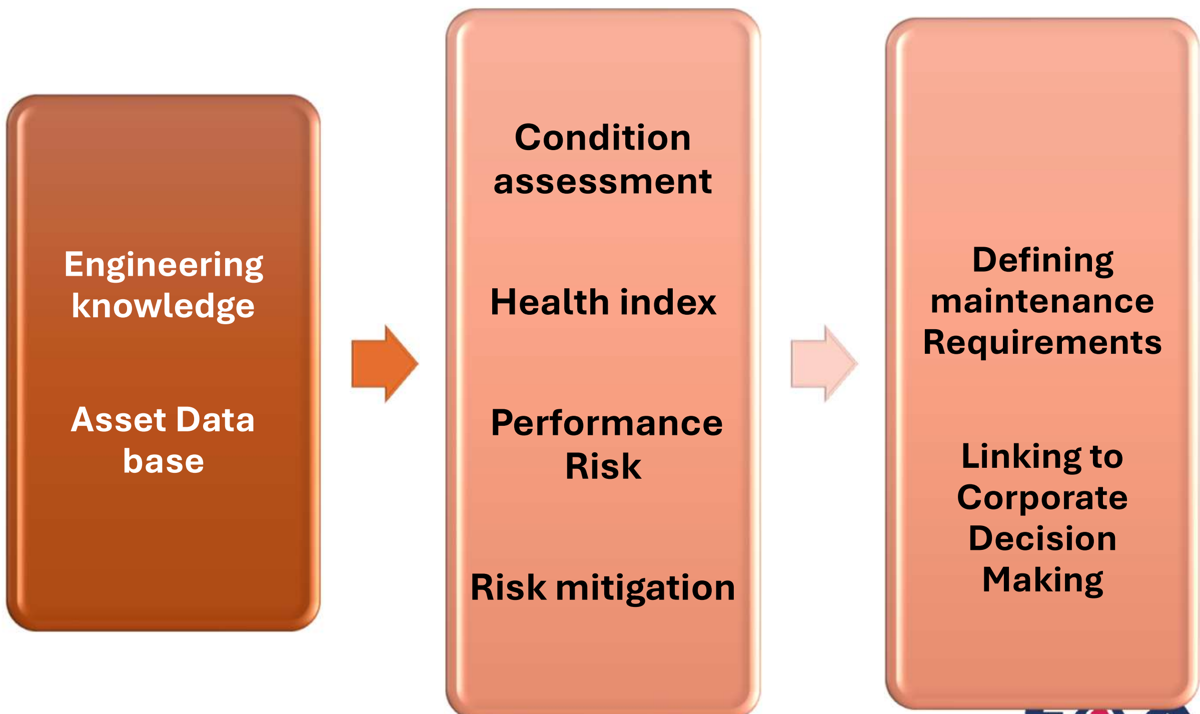
Asset Management
Step-by-Step-procedure

- APM is Converting
 Engineering knowledge,
 Experience and Data
into management information to support corporate decision making

- ***Asset management*** *is defined as the set of* ***coordinated activities*** *that an organization uses to* ***realize value from assets*** *in the* ***delivery of its outcomes or objectives.***



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Key Benefits of Asset Management

- **Performance** improvements
- **Cost** improvements
- **Management of risk**
- **Assurance of business growth**
- **Reliable decision making**
- **Enhanced stakeholder confidence** through **compliance and improved reputation**

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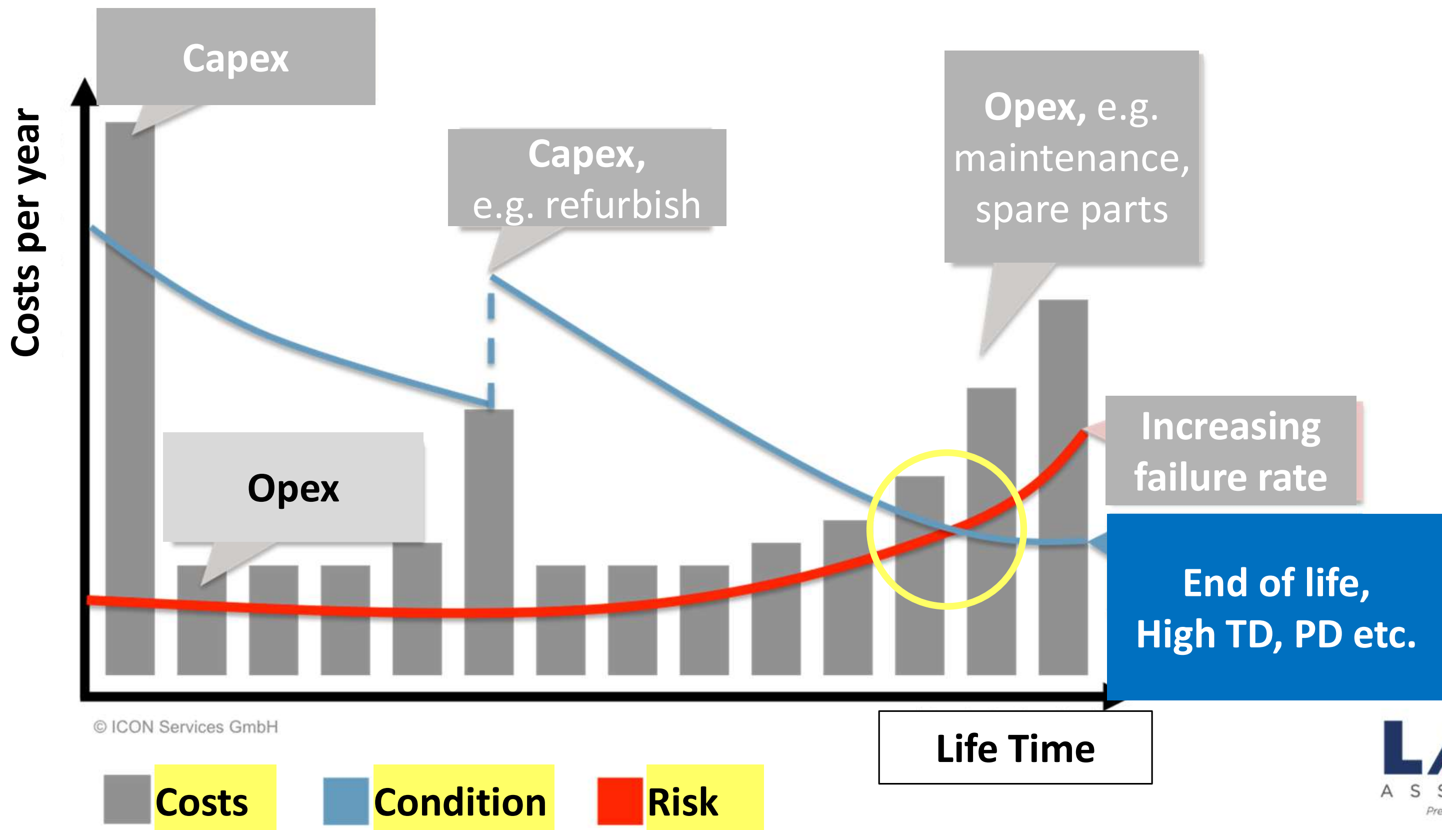
Total cost of Ownership –**Lifecycle analysis** of Asset- CAPEX, OPEX, Conditions, Risk –**Balance between Capex and OPEX**



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ASSET MANAGEMENT

Key benefits of adopting ISO 55000

Balancing the Cost versus Performance over the AM lifecycle

AM is not "**Performing** the **best we can**"

"**Doing what is necessary** to **maintain** the **balance between performance, cost and risk**,

-given **company business values**"

Affordable costs

Desired Performance

- Availability, Reliability-Service level targets
- Public safety
- Staff safety
- Unplanned costs
- Environmental impact

Risk management

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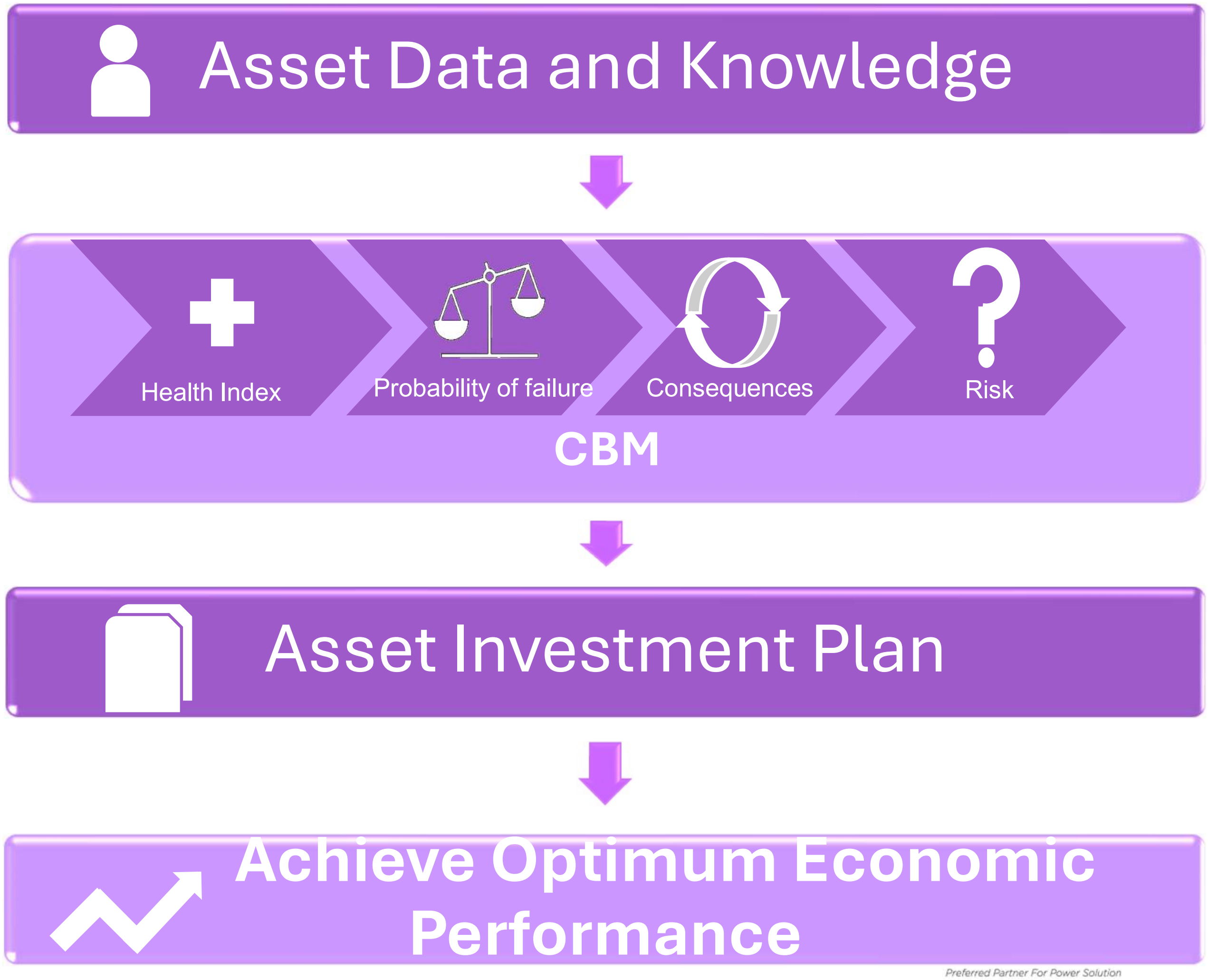
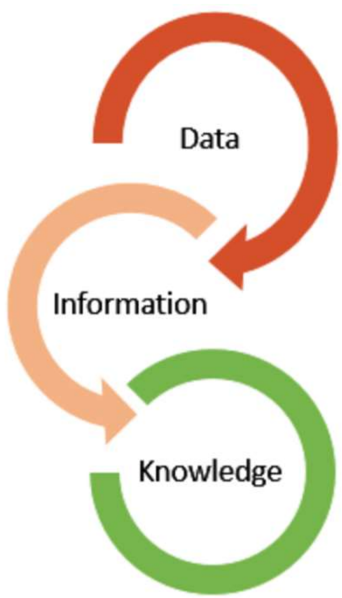
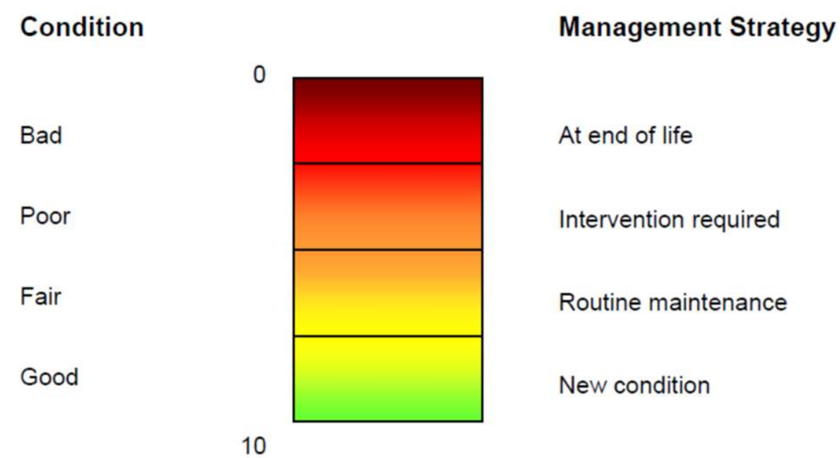
- Asset health index (HI)
- Probability of failure for each asset (POF)
- Consequences of failure
- Financial risk
- Run future scenarios and options



Health Index

- **Systematic collection of available information to define asset condition,**
- **Practical knowledge and experience of assets**
- **Derive a Health index (HI) for each asset**





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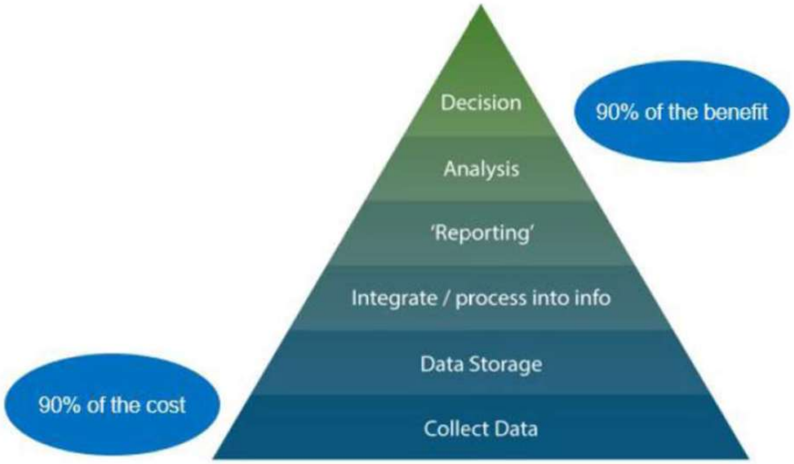
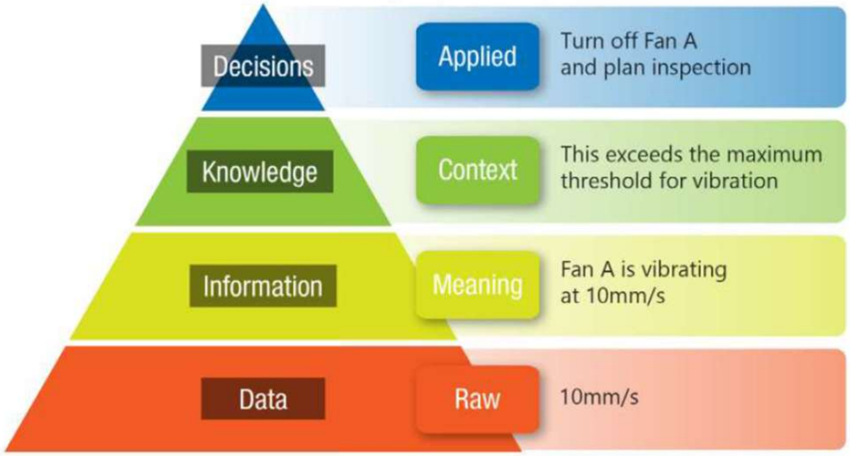
The Value Chain of Information





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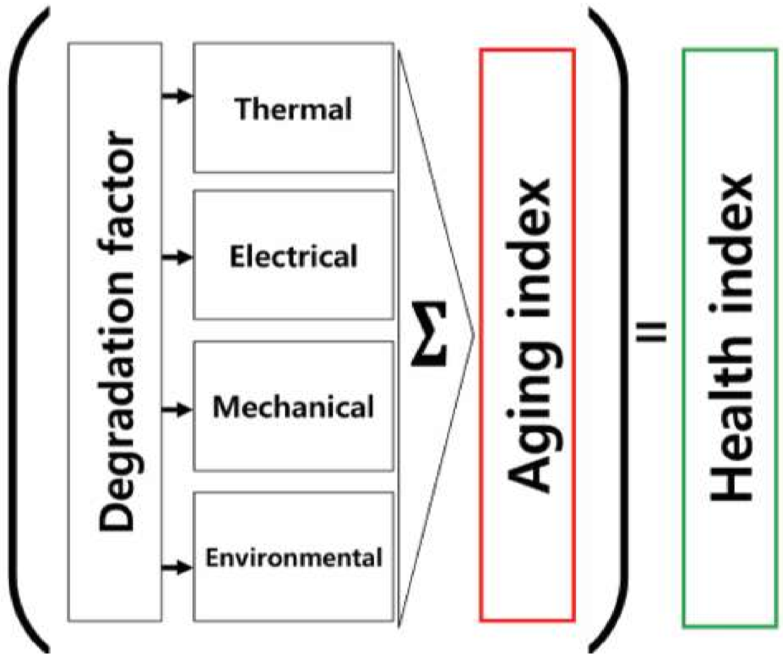
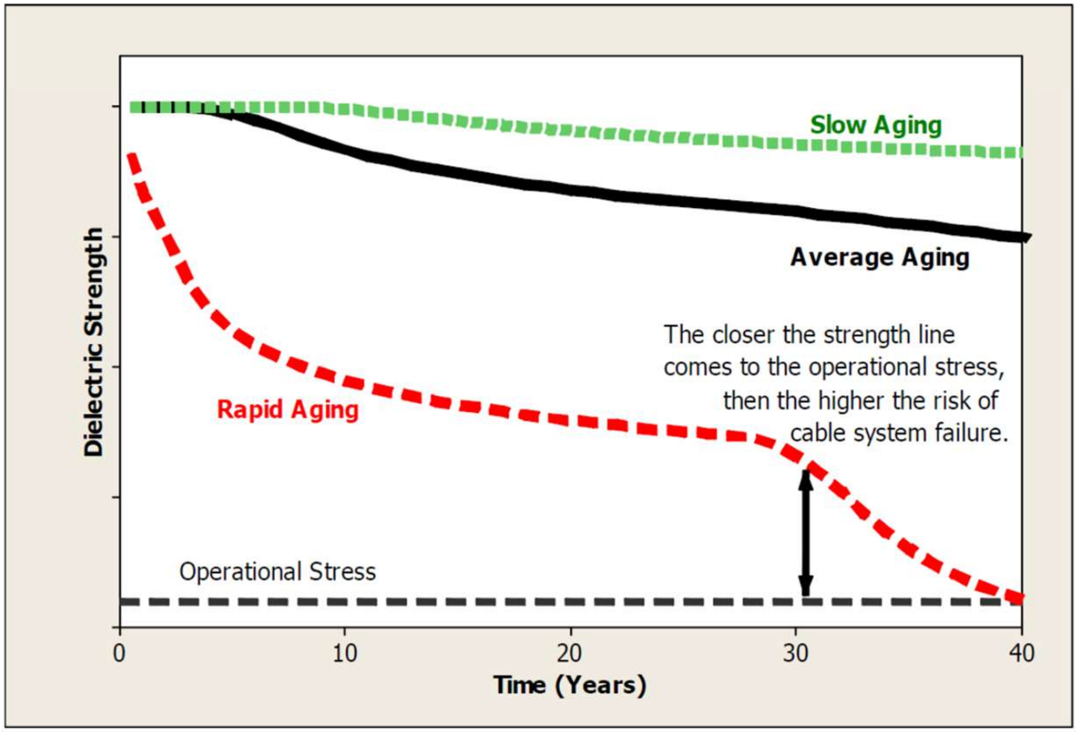
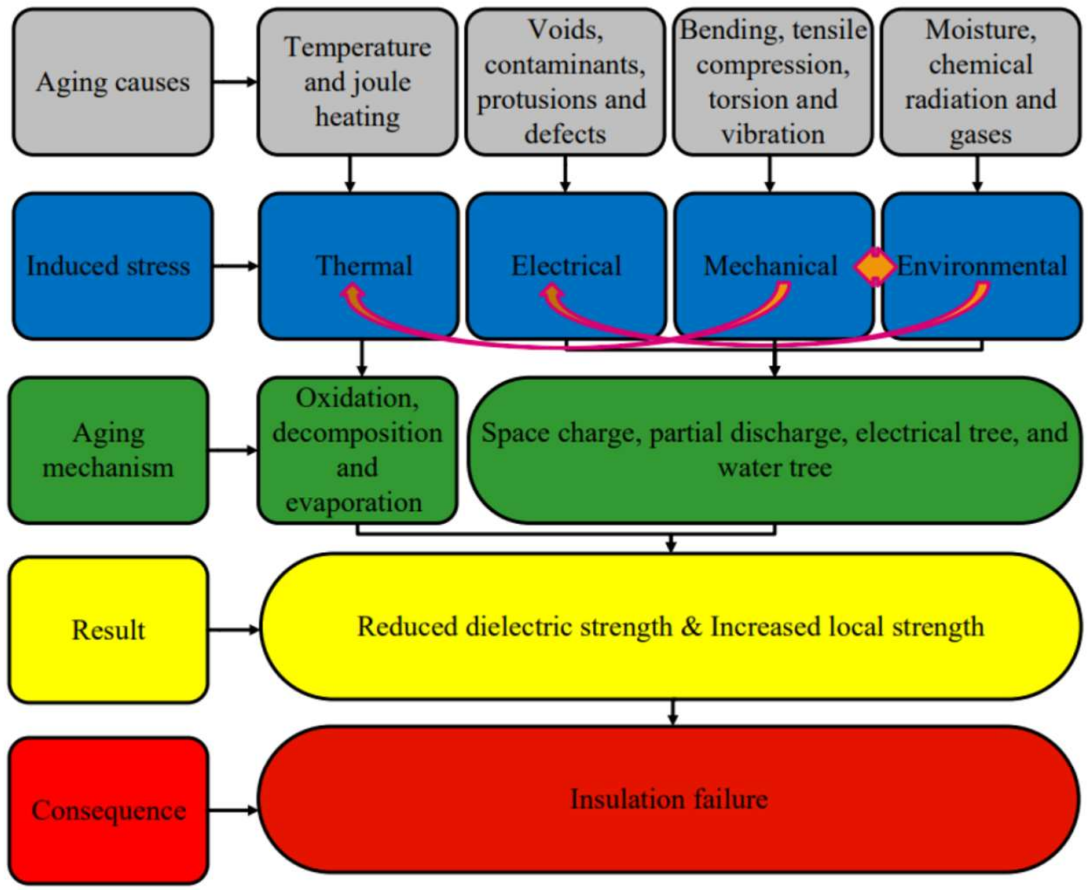
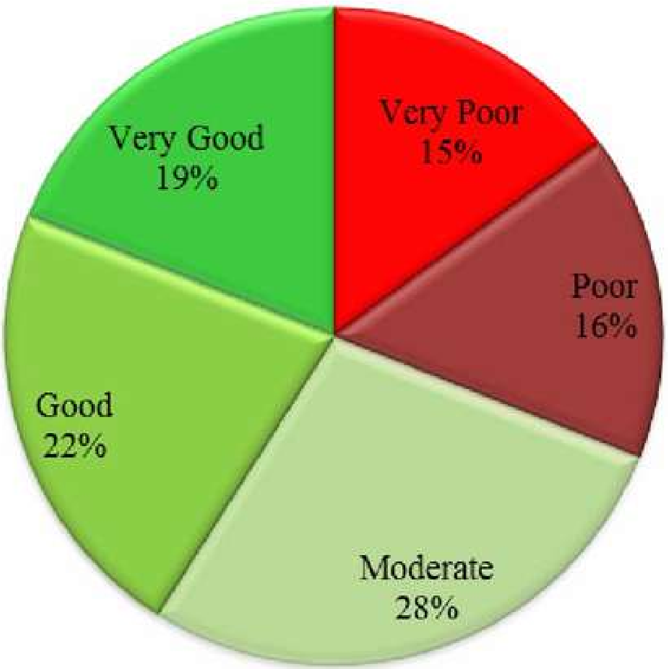

Degradation factor
Thermal
Electrical
Mechanical
Environmental
Σ
Aging index
=
Health index


Slow Aging
Average Aging
Rapid Aging
The closer the strength line comes to the operational stress, then the higher the risk of cable system failure.
Operational Stress
Dielectric Strength
0
10
20
30
40
Time (Years)


Aging causes
Temperature and joule heating
Voids, contaminants, protusions and defects
Bending, tensile compression, torsion and vibration
Moisture, chemical radiation and gases
Induced stress
Thermal
Electrical
Mechanical
Environmental
Aging mechanism
Oxidation, decomposition and evaporation
Space charge, partial discharge, electrical tree, and water tree
Result
Reduced dielectric strength & Increased local strength
Consequence
Insulation failure


Asset data
Asset history
Inspection & diagnostics
Asset technical status
Health Index
Strategy & policy & KPI's
Risk management framework
Asset technical status
Risk Index
Cost analysis
Price control
Timing and forecasting
Decision taking
Urgency
Priority
Maintenance need
Refurbishment
Replacement need



Health Index Code	Health Index Overview
Index-1	Very poor, Red, Need an immediate replacement
Index-2	Poor, Brown, Replacement within the predefined period
Index-3	Moderate, Light green, Maintenance required concerning the time
Index-4	Good, Yellow-green, Normal Maintenance
Index-5	Very good, Green, Wait up to the scheduled maintenance period

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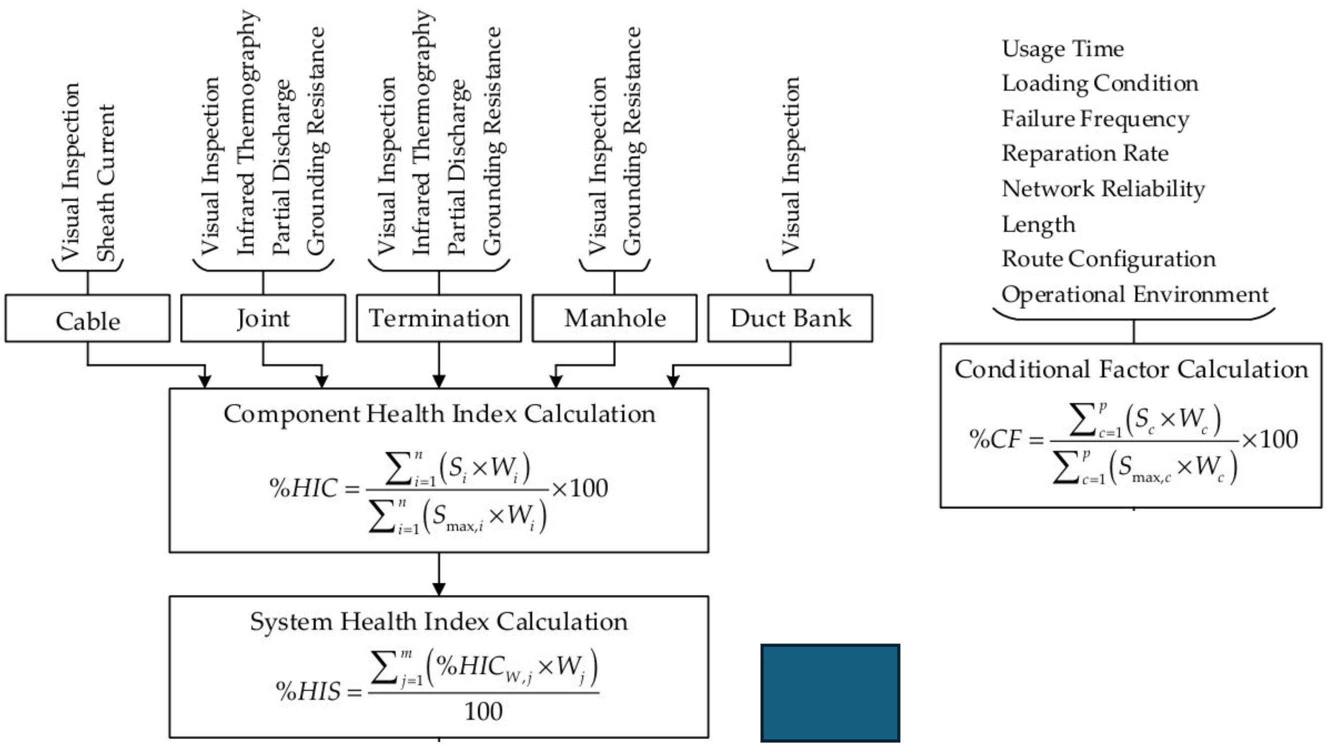

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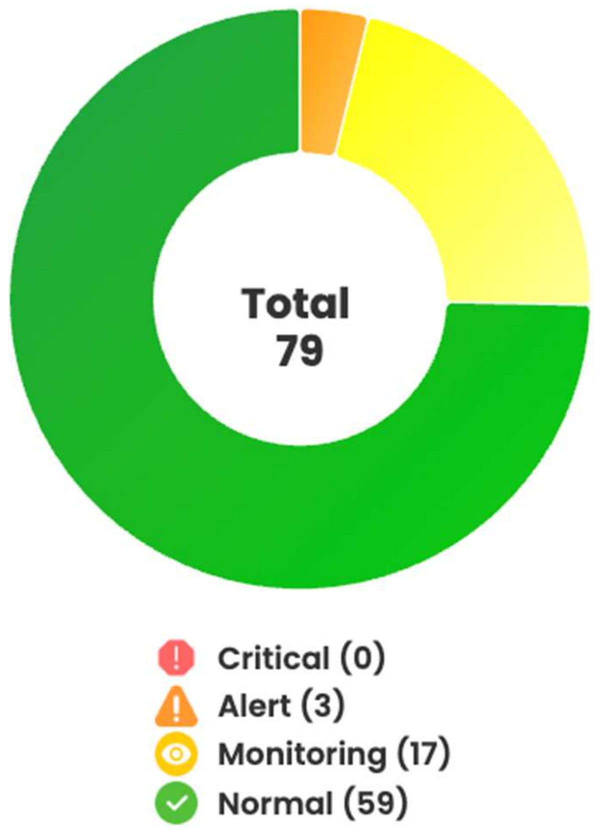
Cable



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1. Dielectric Withstand Test
2. Very low frequency (VLF)
3. Seath test
4. DC Insulation Resistance
5. Partial discharge
6. TDR

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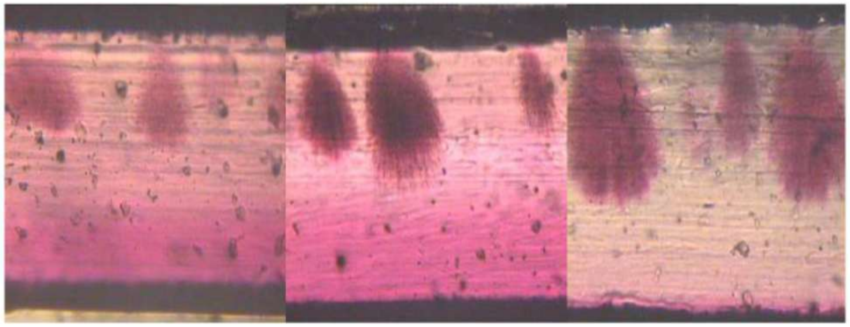
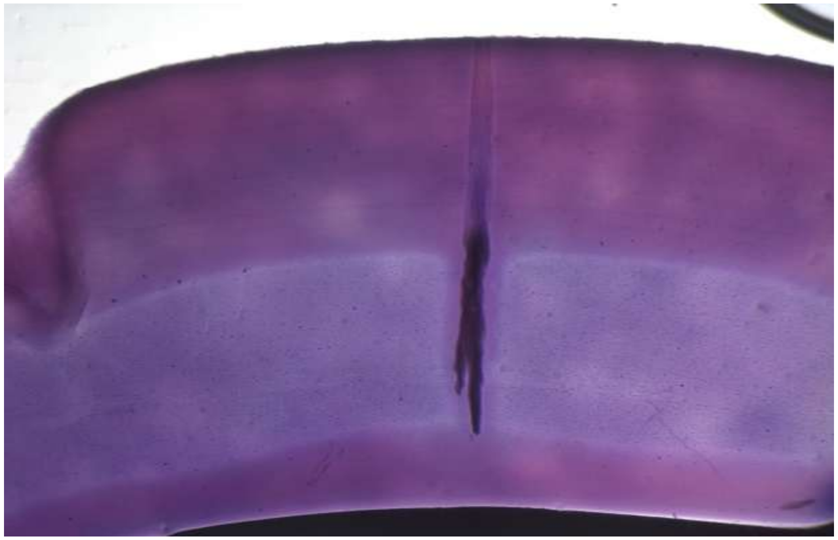
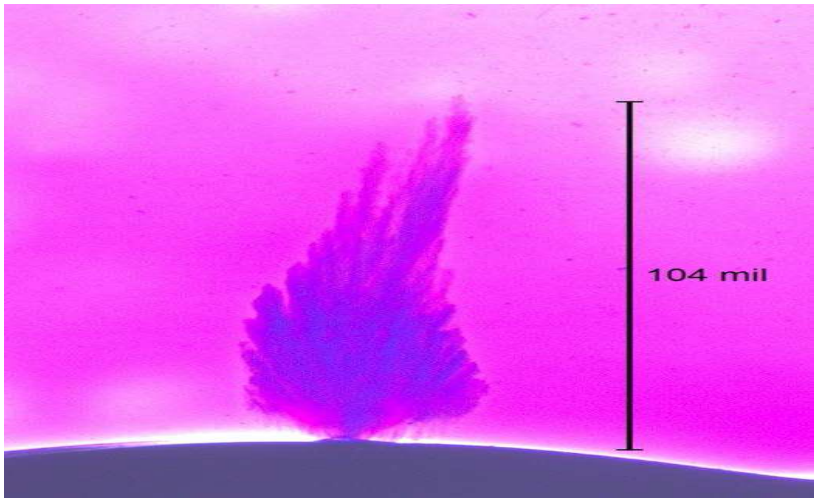
Water Trees in Cable Insulation

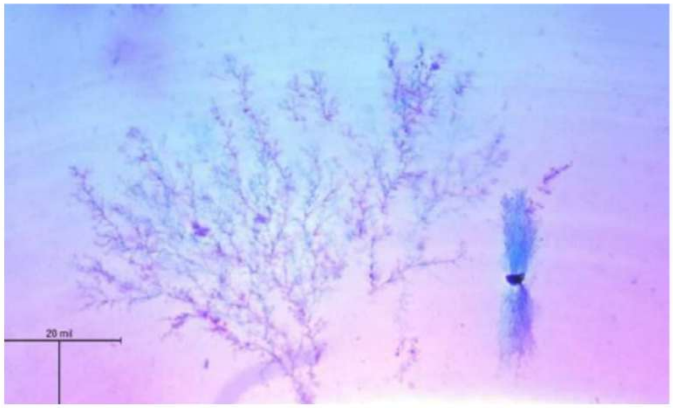
- **Increase in tan δ** over dry insulation
- **Tan δ increases with voltage**

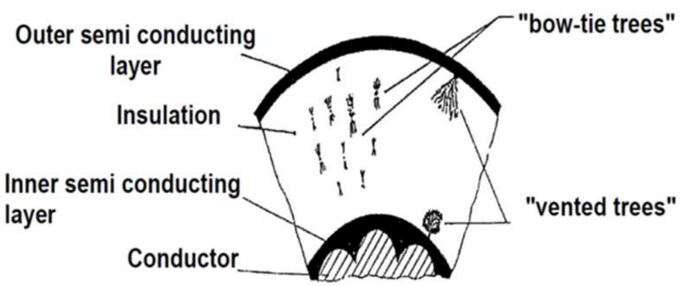
\- Drift of the **water dipoles is non-linear**

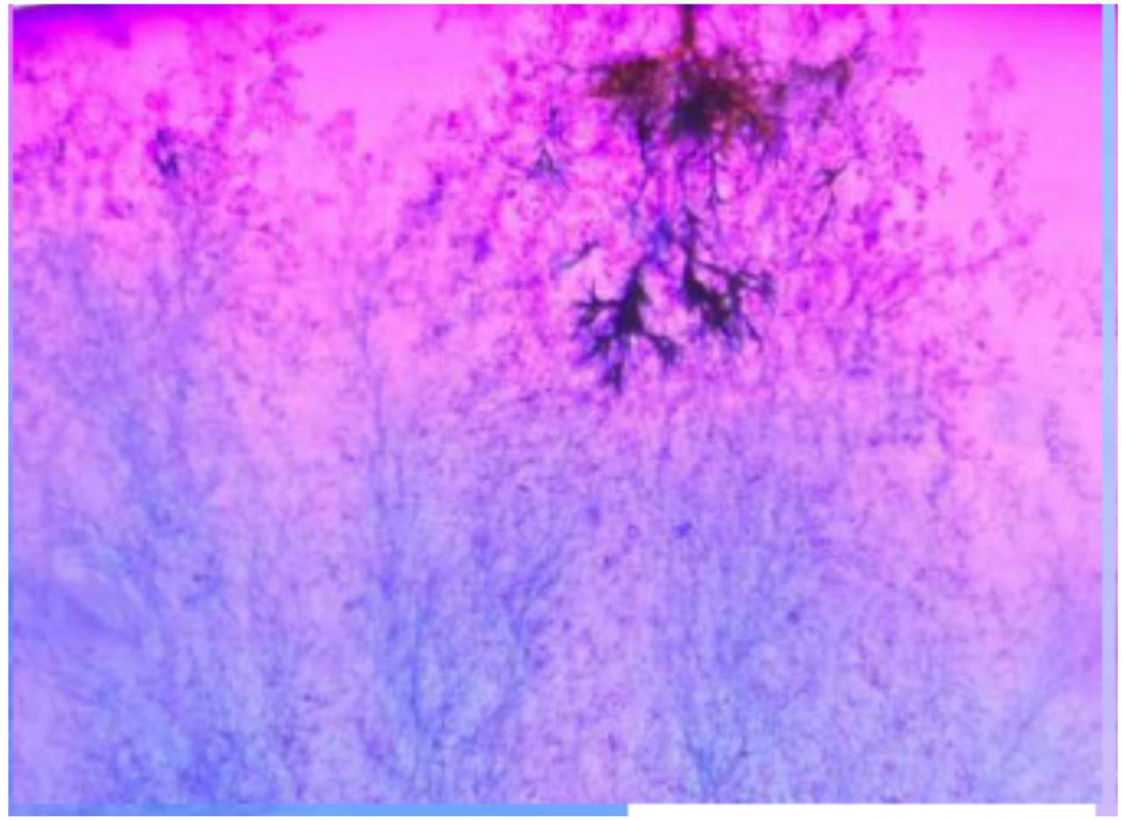












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NO. OF CORES	Number of cables	CABLE MTD DATA			Remark	CABLE MTD DATA AFTER CABLE TERMINATION		
(1/3)		R	Y	B		R	Y	B
3	1	112.31	294.32	31.654	Retermination done	0.571	0.562	0.495
3	1	0.244	0.474	0.917				
3	1	0.268	0.25	0.274				
3	1	1121.1	3913.6	1980.1	Retermination done	0.866	0.955	0.97
3	1	0.244	0.343	0.303				
3	1	15.028	47.051	8.937	Retermination done	1.531	1.355	1.54
3	1	394.63	1841	4422.1	Retermination done	1.94	1.844	1.862
3	1	11.248	7.054	0.755				
3	1	1.043	1.026	1.0371				
3	1	99.363	53.856	123.09	Retermination done	0.516	0.5	0.45
3	1	1.739	1.664	2.547				

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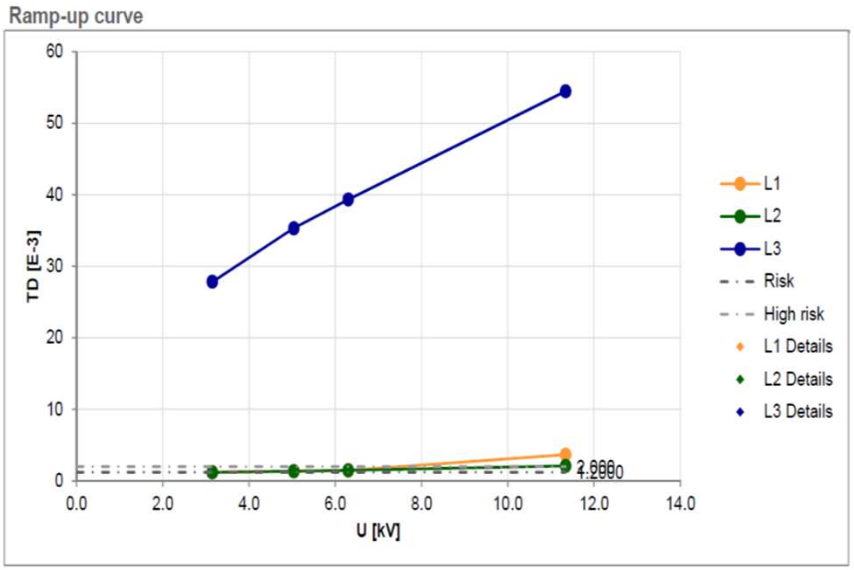
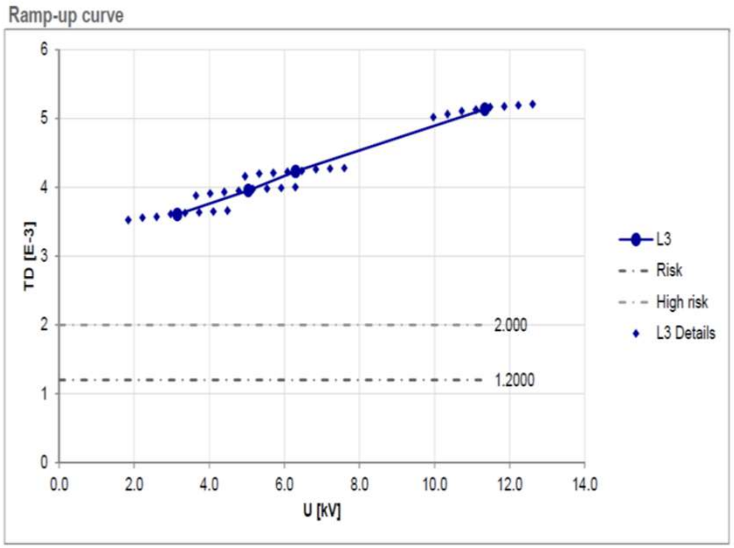
VLF DATA TREND-HIGH MOISTURE CONTENT





Water Trees in Insulation

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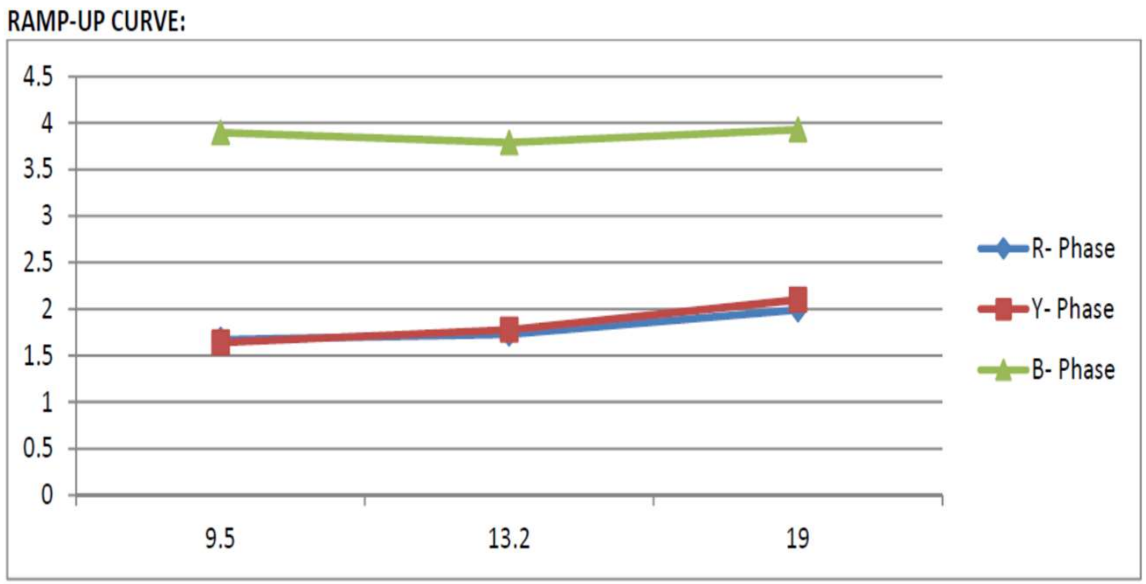
Operating at risk with indication of aged dielectric



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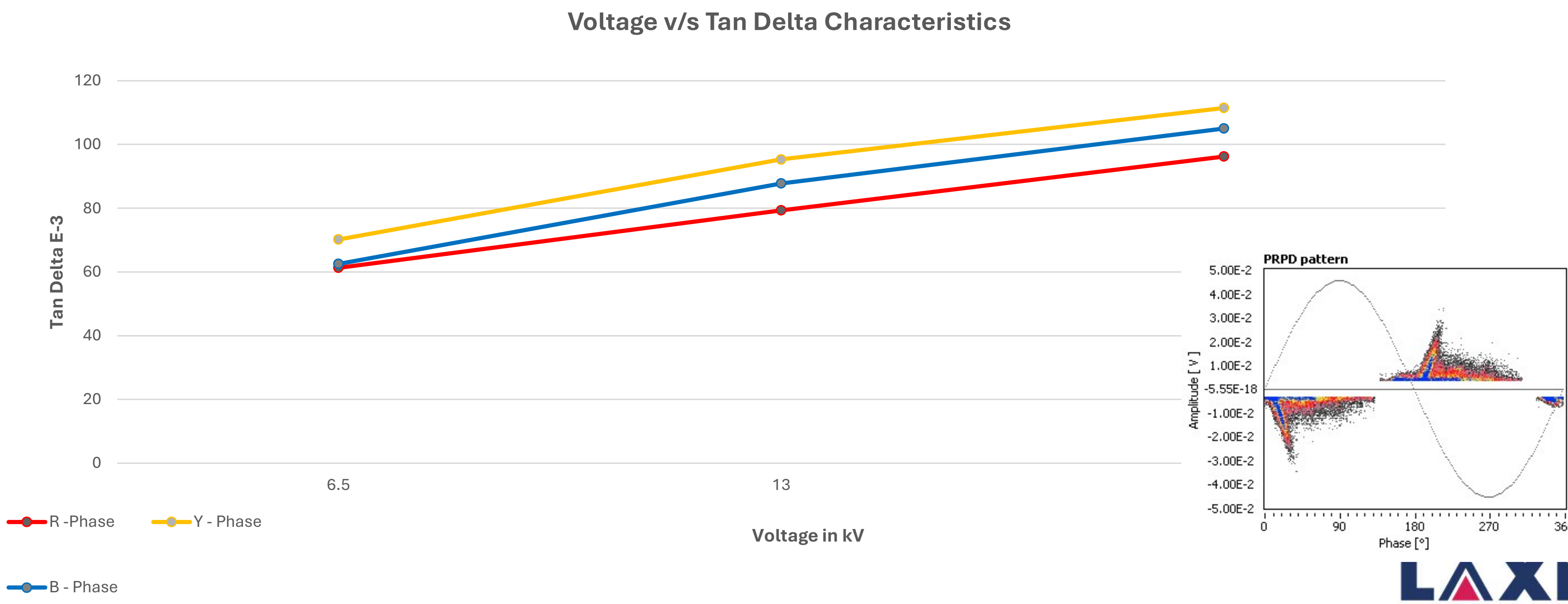

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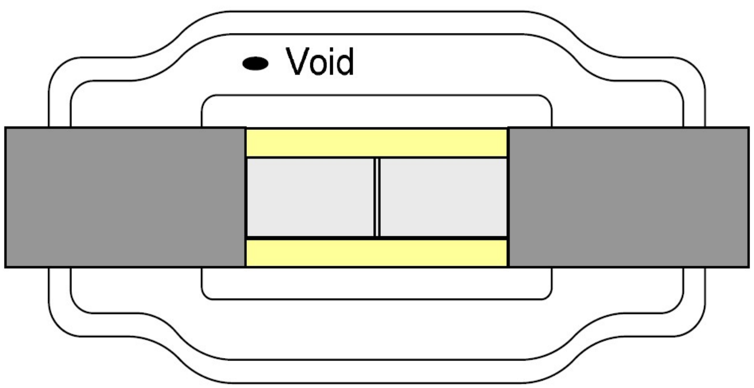
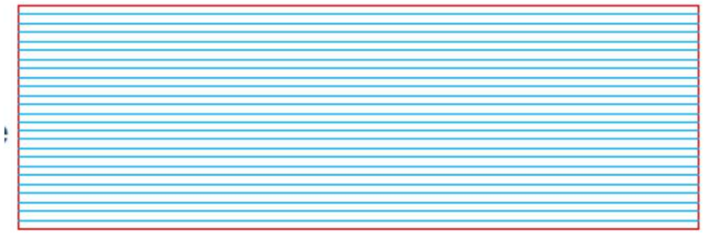
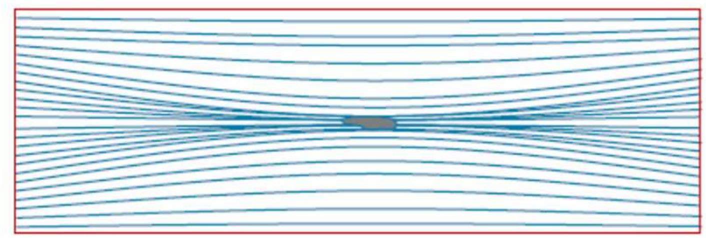
Manufacturing imperfections
(i.e. voids, contaminants),



Lines





IEEE MV Cable Field Testing

IEEE 400 - 2012

Guide for field testing & evaluation of the insulation of shielded power cable systems rated 5kv and above

IEEE 400.1

Field testing of laminated cables rated 5kv and above using DC.

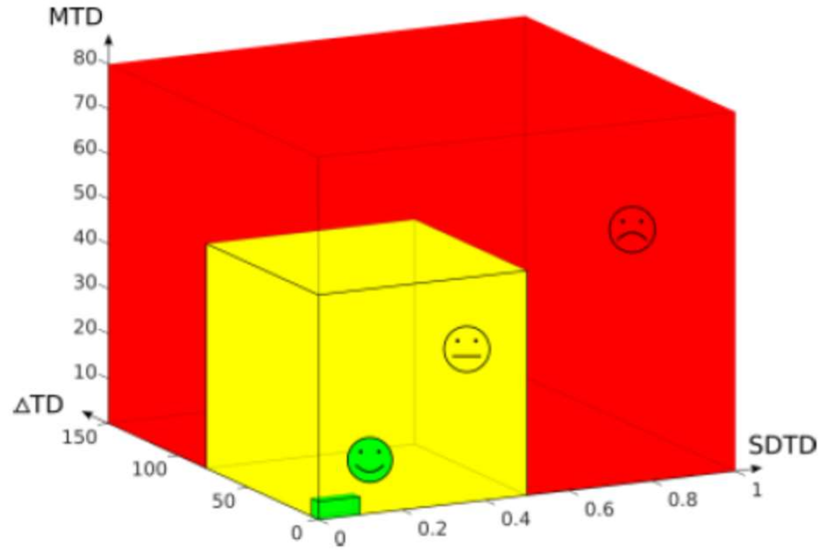
IEEE 400.2 – 2013

Field testing of shielded power cables using very low frequency VLF

IEEE 400.3

PD testing of shielded power cables in the field environment

Indicators	*Calculations*
tan δ stability (SDTD)	Standard deviation of 6-10 measurements at Uo
delta tan δ (ΔTD)	Difference of the average values at 1.5 Uo and 0.5 Uo
mean tan δ (MTD)	Average value of 6-10 measurements at Uo



Evaluation criteria for cables aged through operation according to the IEEE

Condition assessment	VLF-TD time stability (VLF-TDTS) measured by standard deviation at U_0 [10^{-3}]			Differential VLF-TD (VLF-TDT) difference in mean VLF-TD between 0.5 U_0 and 1.5 U_0 [10^{-3}]			Mean VLF-TD at U_0 [10^{-3}]	
	XLPE cables	Paper-insulated mass-impregnated cables		XLPE cables	Paper-insulated mass-impregnated cables		XLPE cables	Paper-insulated mass-impregnated cables
No action required	< 0.1	< 0.1	and	< 5	-35 to 10	and	< 4	< 85
Further study advised	0.1 to 0.5	0.1 to 0.4	or	5 to 80	-35 to -50 or 10 to 100	or	4 to 50	85 to 200
Action required	> 0.5	> 0.4	or	> 80	< -50 or > 100	or	> 50	> 200

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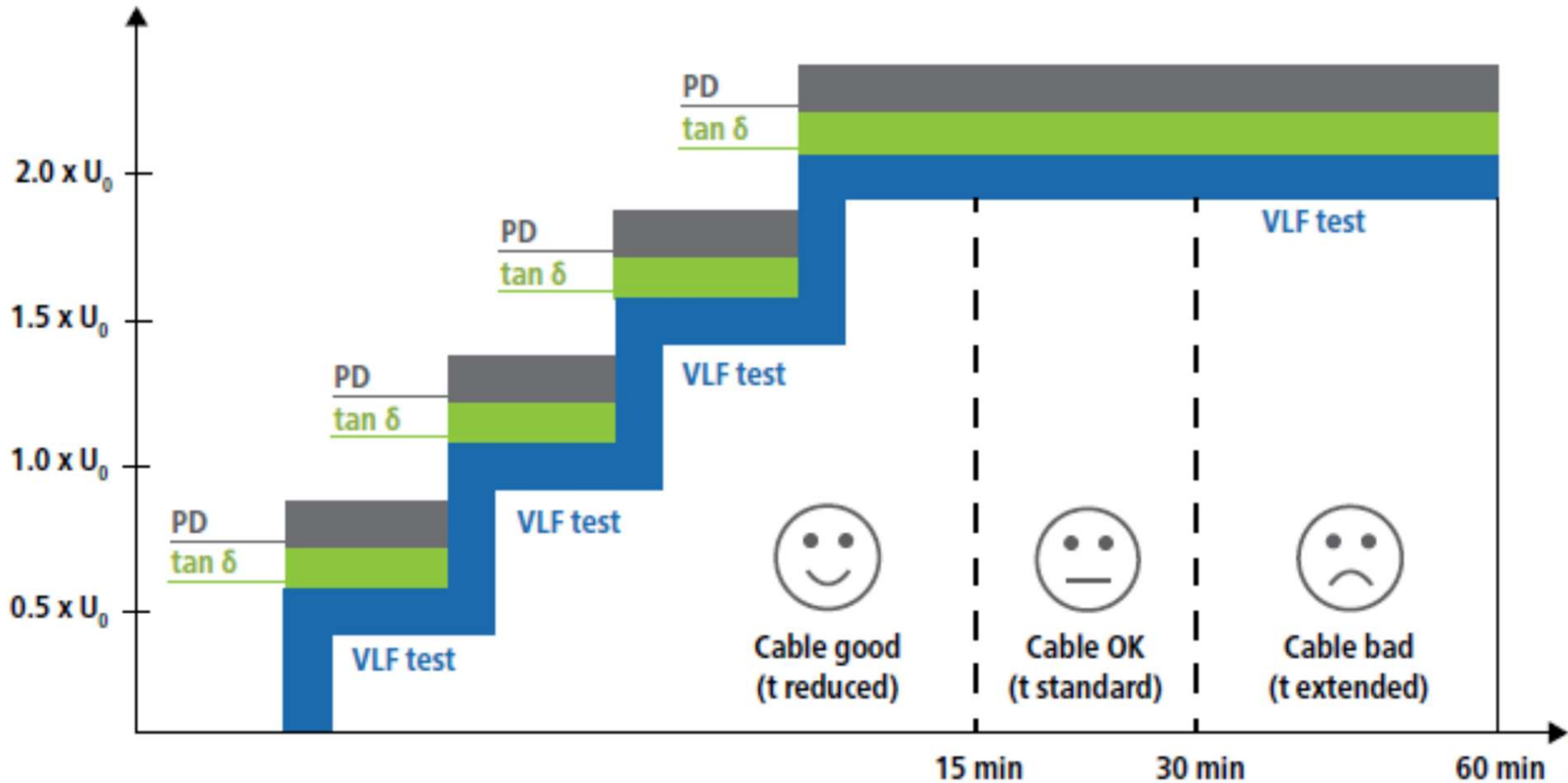
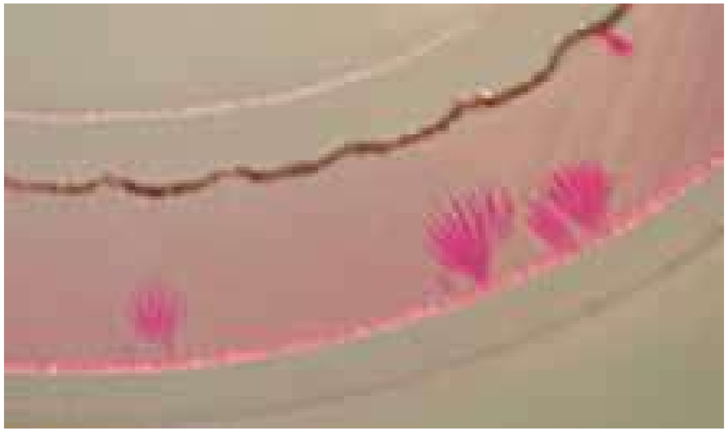
VLF Test + tan δ + PD = Full MWT



Partial discharge measurement

- Partial discharge measurement in accordance with standard IEC 60270.
- Partial discharges (PD) occur at faults in the cable
  - electrical trees,
  - joints and terminations



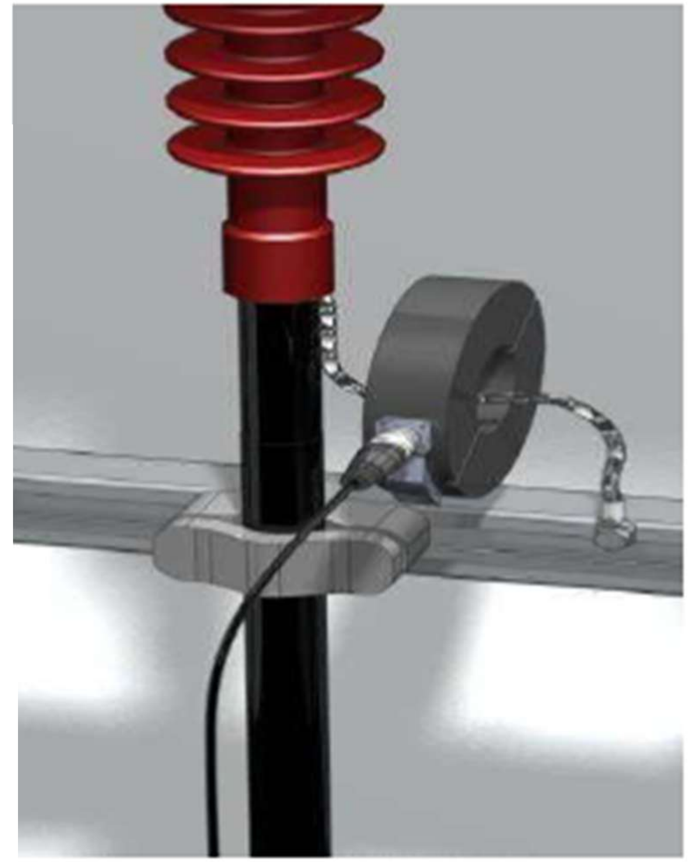
Water trees, made visible through colouring

Electrical trees

Un-conventional Method

- This methods use HFCT (High frequency Current Transformer)

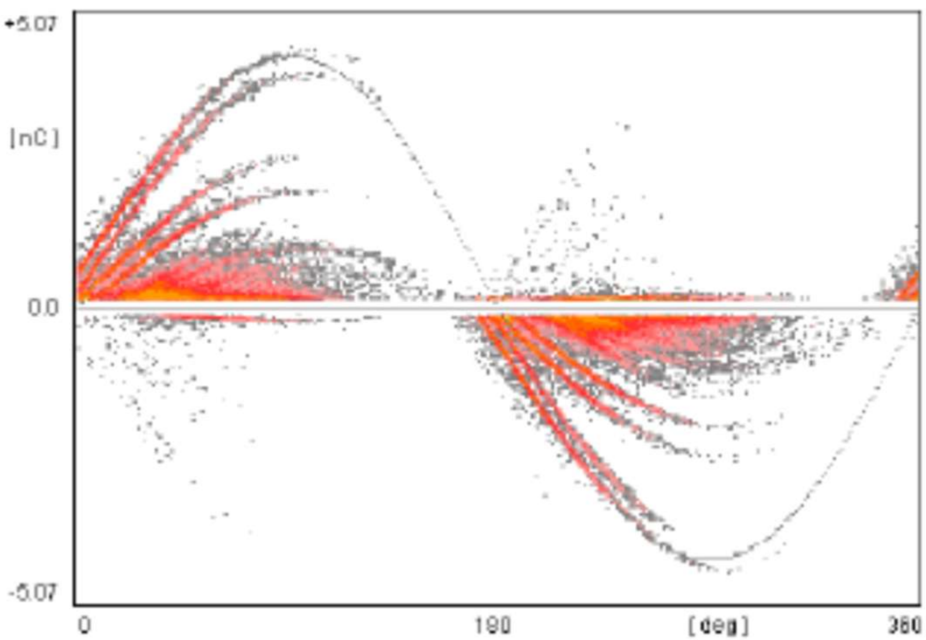
HFCT Sensor -140mm

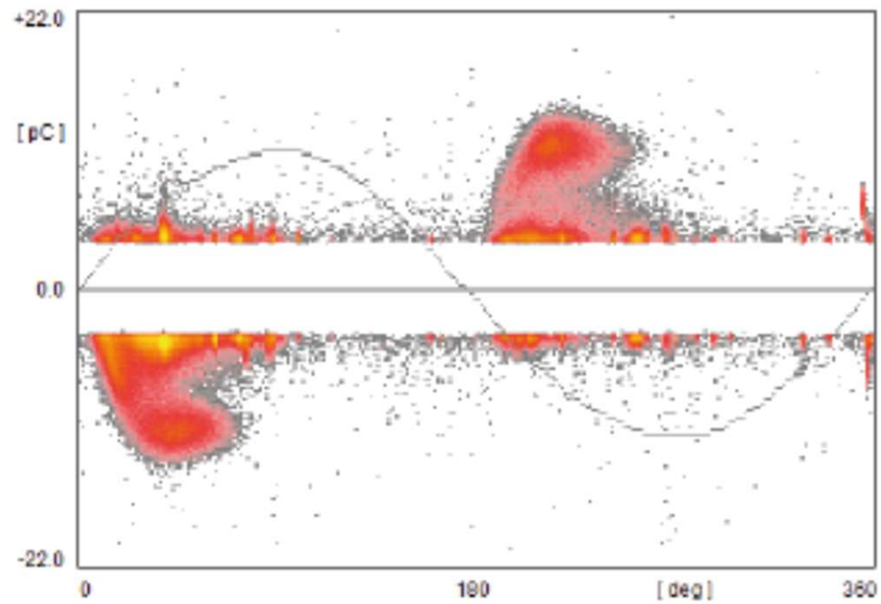


HFCT Sensor-39mm

Void

Internal PD





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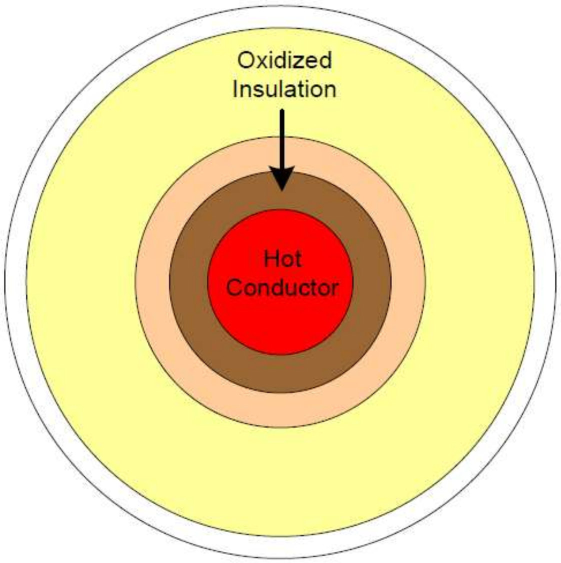
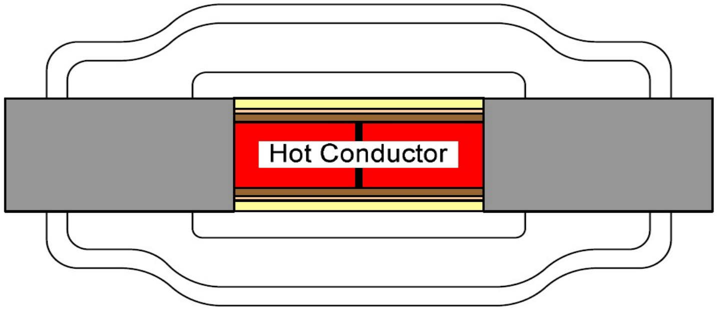
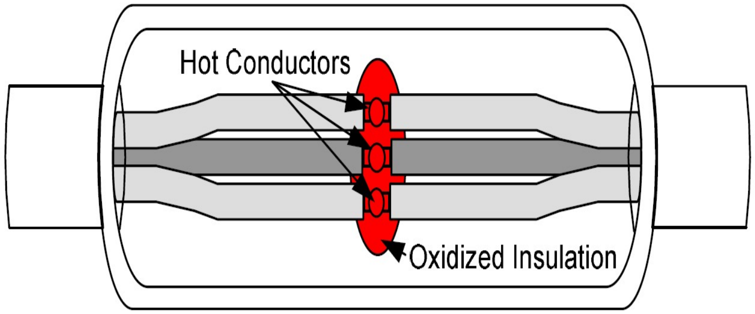
Thermal

Excessive conductor current for a given environment and Operating conditions



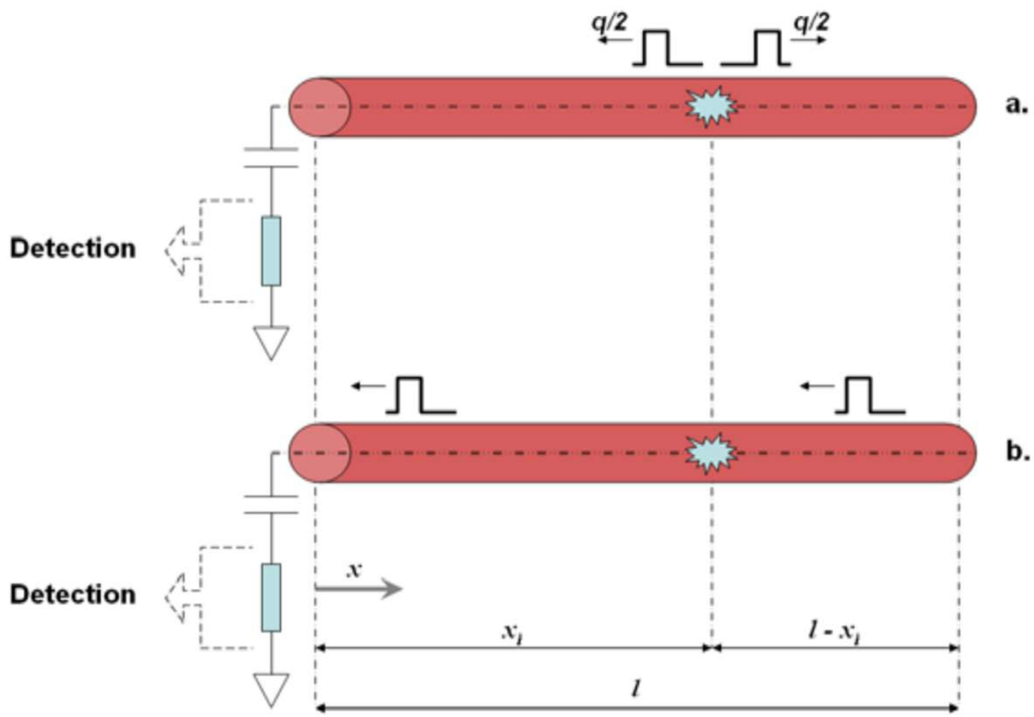




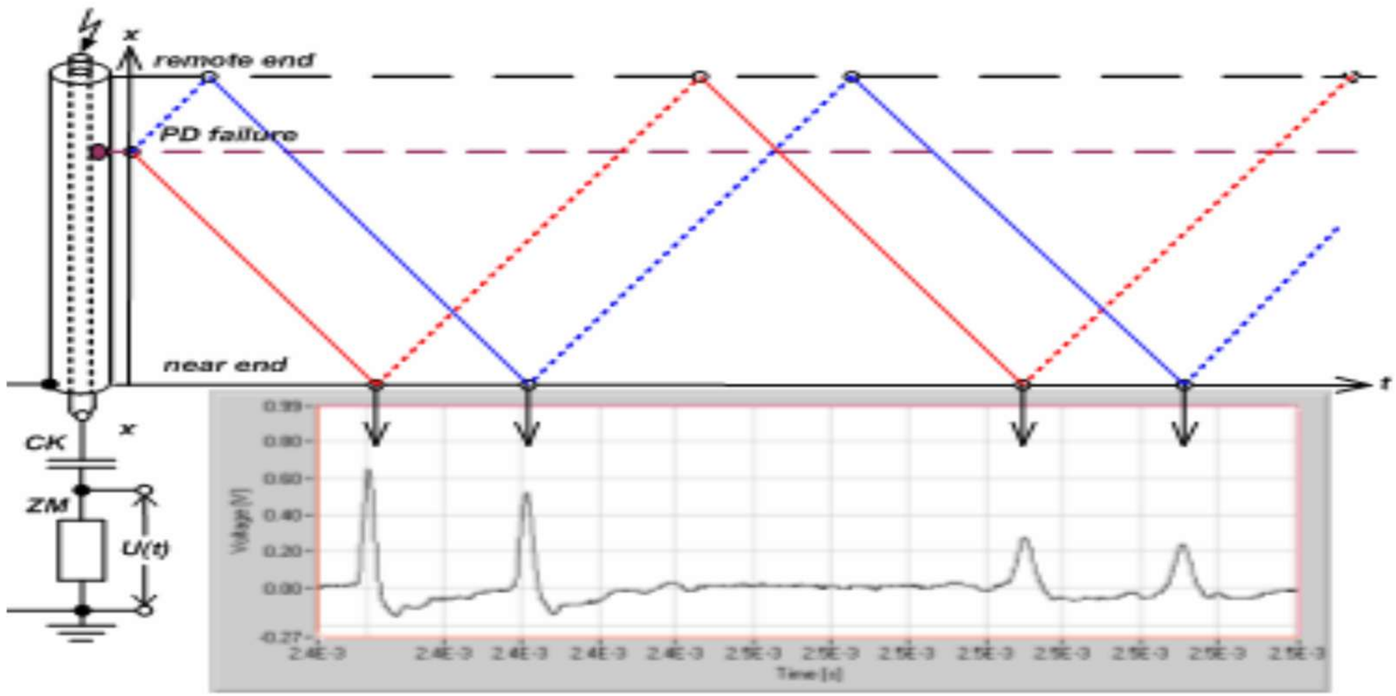
TDR Method

Due to the **symmetrical configuration** of power cables:

- Each **PD event produces two equal current pulses,**
- i.e. Pulse charge magnitude ***q / 2*** **travels away from the PD source in both directions,**



TDR Method



Principle of the PD fault location using the time domain reflectometry, cable length 1705 m, PD site from near end 1297 m

Principle of the PD fault location using the time domain reflectometry, cable length 1705 m, PD site from near end 1297 m

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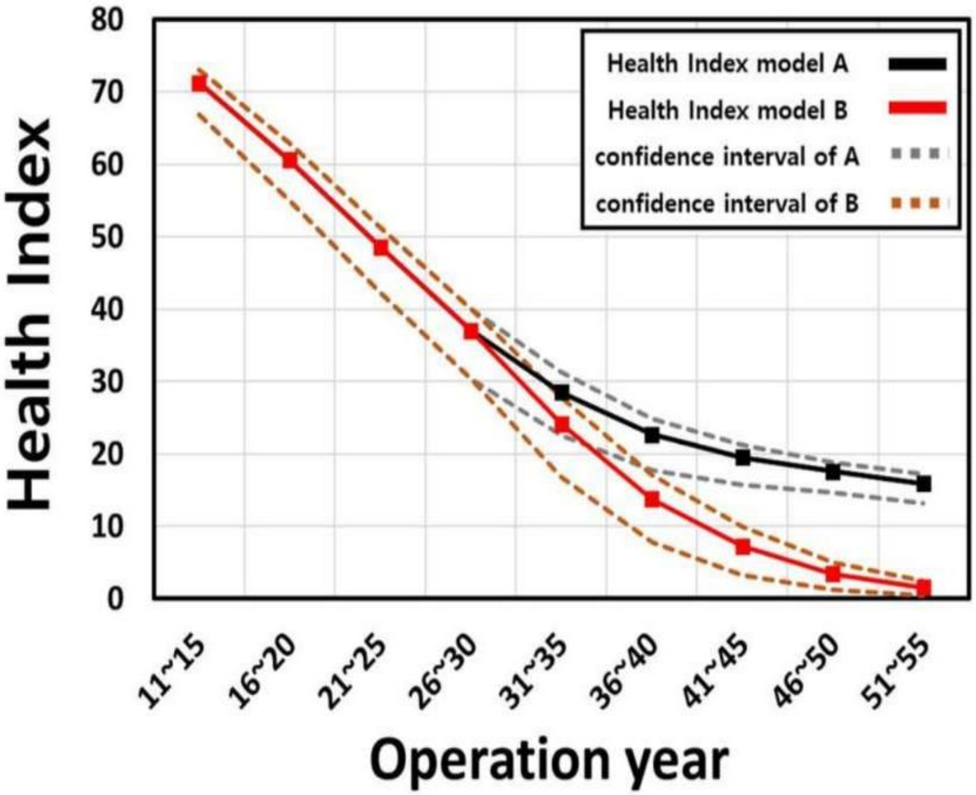

$$\%HI_{C;j} = \frac{\sum_{i=1}^{M}(S_{TR;i} \times W_{TR;i})}{\sum_{i=1}^{M}(S_{TR;MAX} \times W_{TR;i})} \times 100$$

%OHI	Indicator	Description
90%-100%	Good	The system is good condition and does not need immediate action.
60%-90%	Moderate	The system is moderate condition and needs particular attention.
less than 60%	Poor	The system is approaching its end of life.

$$\%HI_{CS} = \sum_{j=1}^{N}\left(\frac{\%HI_{C,j} \times \%W_{C;j}}{100}\right)$$

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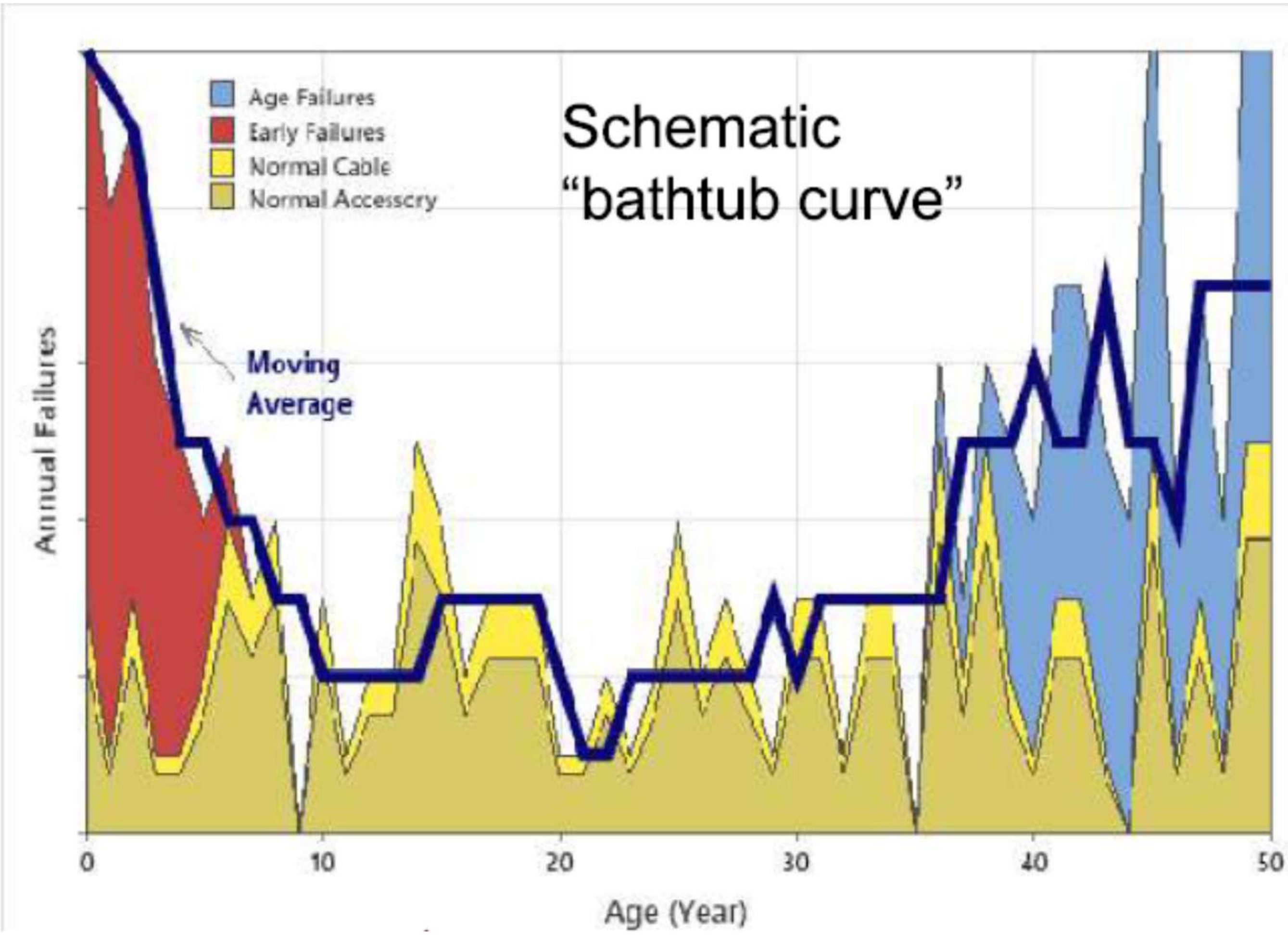
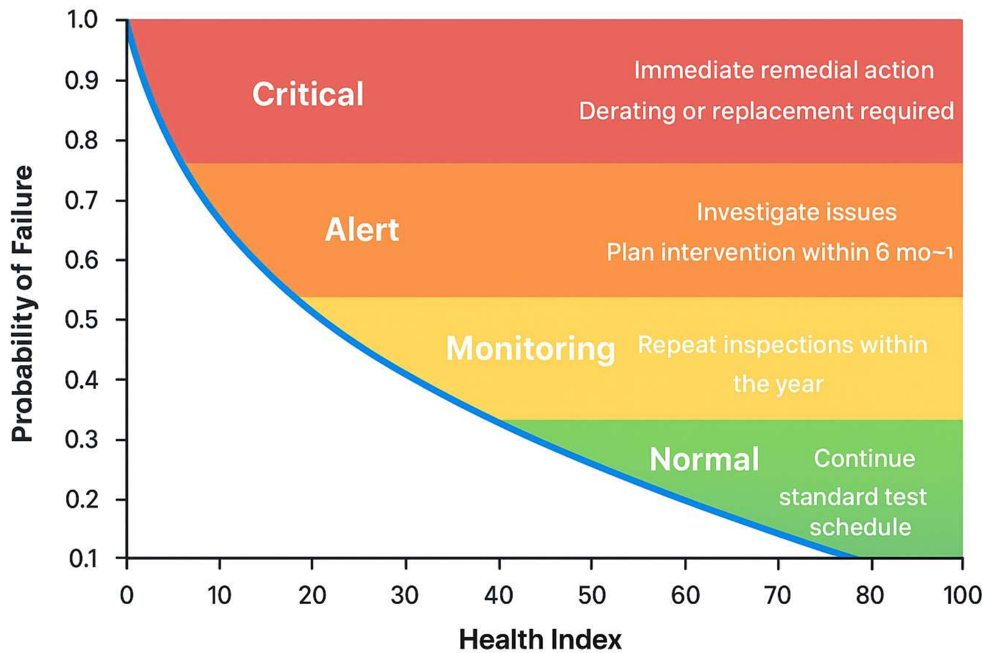

Age Failures
Early Failures
Normal Cable
Normal Accessory
Schematic
"bathtub curve"
Moving
Average
Annual Failures
0
10
20
30
40
50
Age (Year)



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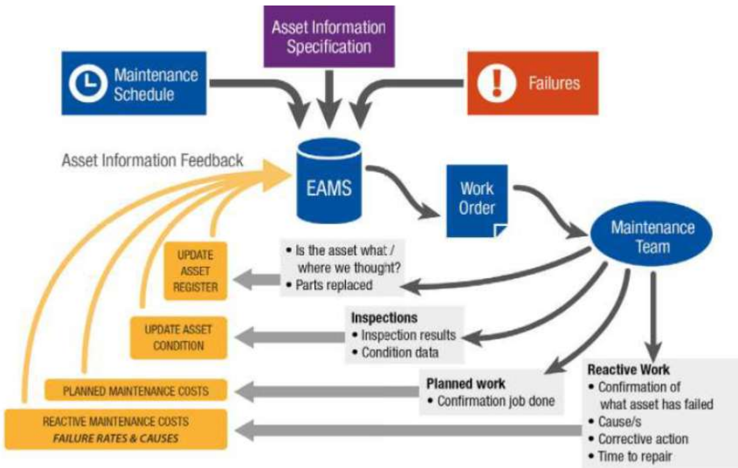
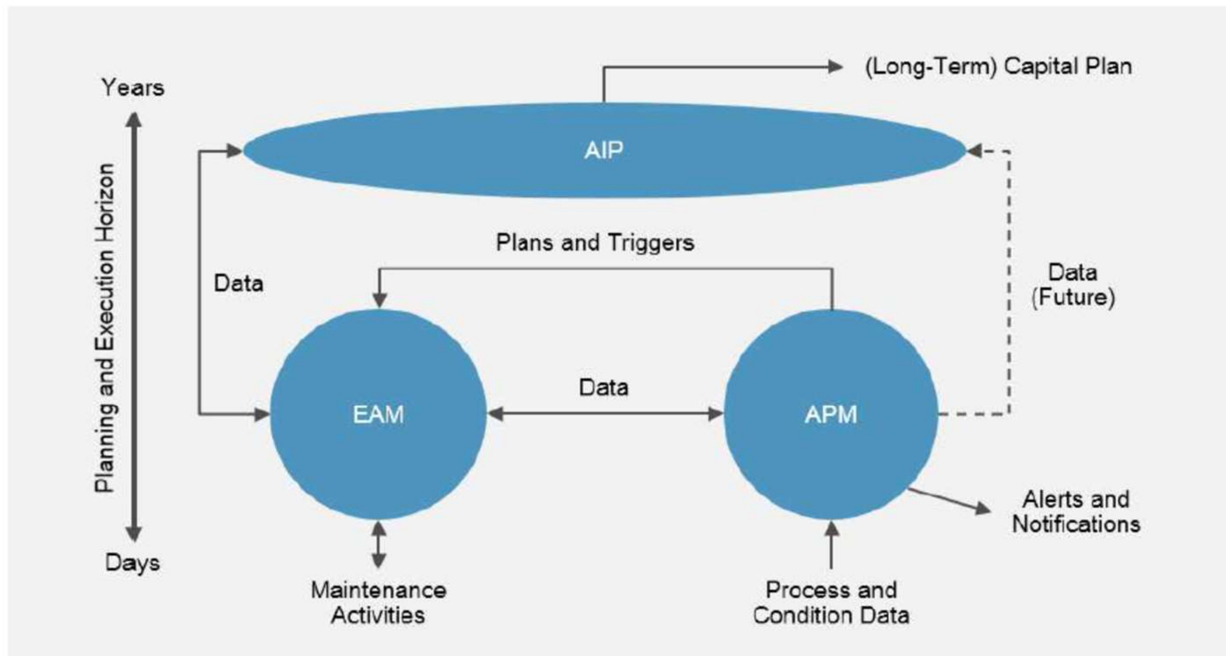


Asset Information Specification
Maintenance Schedule
Failures
Asset Information Feedback
EAMS
Work Order
Maintenance Team
UPDATE ASSET REGISTER
• Is the asset what / where we thought?
• Parts replaced
UPDATE ASSET CONDITION
Inspections
• Inspection results
• Condition data
PLANNED MAINTENANCE COSTS
Planned work
• Confirmation job done
REACTIVE MAINTENANCE COSTS
FAILURE RATES & CAUSES
Reactive Work
• Confirmation of what asset has failed
• Cause/s
• Corrective action
• Time to repair



Years
Planning and Execution Horizon
Days
(Long-Term) Capital Plan
AIP
Plans and Triggers
Data
Data (Future)
EAM
Data
APM
Alerts and Notifications
Maintenance Activities
Process and Condition Data

ISO 55000

It is an **improvement of PAS 55**

❑ISO 55000:2014 Asset management – Overview, principles and terminology (Why)

❑ISO 55001:2014 Asset management – Management Systems – Requirements (What)

❑ISO 55002:2014 Guidelines for the application of ISO 55001(How)

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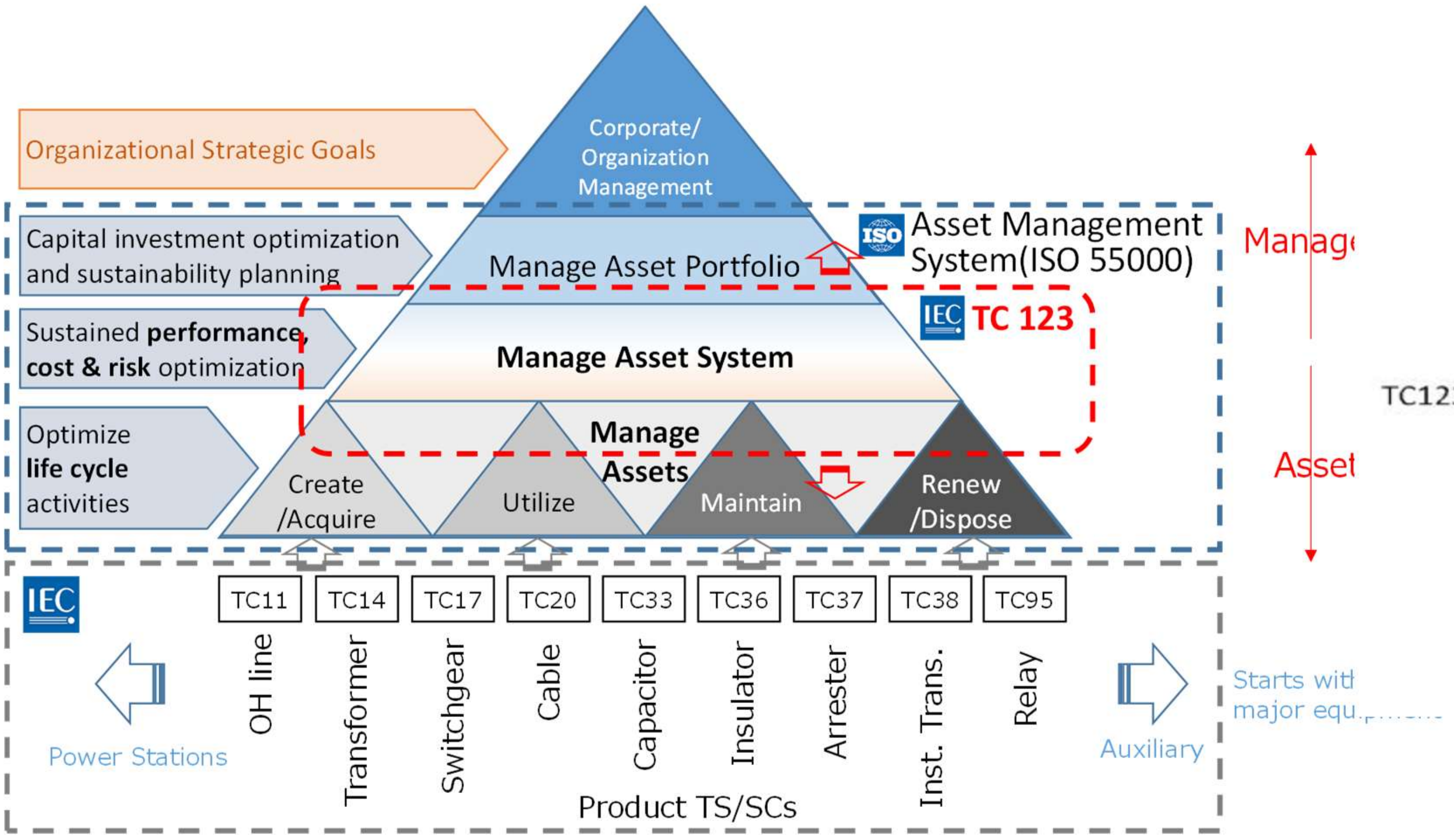
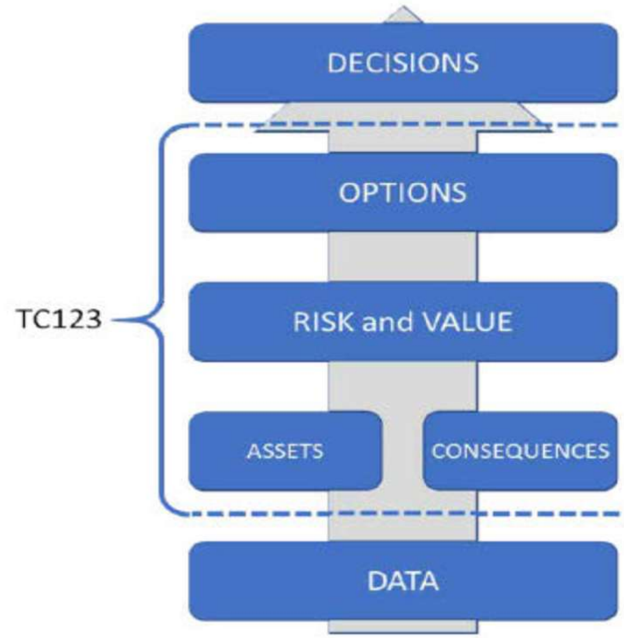
Objectives of ISO 55000

- **Alignment** between **technical, financial and operational decisions** that collectively enable the **achievement of corporate objectives.**

- **Leadership** and **commitment from top management** in **using asset management**.

Scope of TC 123





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